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The Effect of a Hip Strengthening Program on Mechanics during Running and during a Single Leg Squatting

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The authors do not have any conflicts of interest.

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ABSTRACT

Study Design: Block randomized controlled trial

Objectives: To investigate whether a hip strengthening program alters hip mechanics during running and during a single leg squat.

Background: Abnormal movement patterns during running and single leg squatting have been associated with a number of running related injuries in females. Therapeutic interventions for these aberrant movement patterns typically include hip strengthening. While these strengthening programs have been shown to improve symptoms, it is unknown if the underlying mechanics during functional movements are altered.

Methods: Twenty healthy females with excessive hip adduction during running, **determined by an instrumented gait analysis**, were recruited. Subjects were matched based on age and running mileage to either a strength training group or a control group. The strength training group underwent a 3x/week, 6-week hip strengthening program that included training in single leg squatting. **The control group did not receive an intervention, but maintained their current running mileage**. Using a hand held dynamometer and standard motion capture procedures, hip strength, running and single leg squat mechanics were compared before and after the strengthening program.

Results: While hip abductor and external rotation strength increased significantly (*p<0.005*) in the strength training group, there were no significant changes in hip or

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knee mechanics during running. However, during the single leg squat, hip adduction, hip internal rotation, and contralateral pelvic drop all decreased significantly (p=0.006, p=0.006, p=0.02, respectively). The control group exhibited no changes in hip strength, nor in the single leg squat or running mechanics at the conclusion of the six week study.

Conclusion: Hip strengthening that included single leg stance training did not alter running mechanics, but did improve single leg squat mechanics. These results suggest that hip strengthening and neuromuscular reeducation that is not specific to running does not alter abnormal running mechanics.

Level of Evidence: Therapy, Level 2a

***Key Words**: biomechanics/lower extremity, hip, knee, running*

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INTRODUCTION

Abnormal hip and knee mechanics have been associated with a number of running-related injuries.[11,27,29,32,33,34,35,38,39,40,41] These injuries include tibial stress fractures,[32] iliotibial band syndrome[29] and patellofemoral pain syndrome.[11,27,33,34,35,38,39,40,41] In particular, patellofemoral pain syndrome (PFPS) has been linked with excessive hip adduction,[11,41] hip internal rotation,[11,38,39,40] contralateral pelvic drop, [11,41] and knee external rotation[41] during running. These excessive movements have also been identified during a single leg squat,[41] single leg jump landing,[4,38,41] and step down maneuvers in females with PFPS.[38] This movement pattern is thought to increase frontal plane loading of the knee and the dynamic quadriceps angle, resulting in lateral tracking of the patella and abnormal loading of the patellofemoral joint.[7,18,23,27,33,35]

Several studies suggest that females with PFPS demonstrate weakness of the musculature that control hip adduction, hip internal rotation, contralateral pelvic drop and knee external rotation.[5,6,8,19,39] Thus, hip strengthening is often advocated to improve hip mechanics[26] with the hope of reducing the incidence of or symptoms related to PFPS.[5,15,19,27,28] It has been shown that these programs improve strength[3,24,28] and reduce or may prevent symptoms.[3,15,22,24,28] However, it is not clear whether strengthening the hip actually results in a change in abnormal hip and knee mechanics during functional activities such as running and squatting.

Only one study has examined the effect of hip strengthening on normal running kinematics in healthy individuals. Snyder et al. (2008) examined the effects of strengthening the hip abductors and external rotators on hip and knee mechanics in

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healthy, active females.[37] Aside from a small *increase* in hip adduction excursion, no changes in hip and knee kinematics were noted. However, it should be noted that their study did not focus on individuals with abnormal mechanics. Thus, the potential for changes in mechanics may have been limited.

To date, only one study has examined the effects of hip strengthening in individuals with abnormal lower extremity mechanics. Mascal et al., (2003) reported on a case study involving a female with anterior knee pain.[24] This subject demonstrated excessive hip adduction, internal rotation and contralateral pelvic drop during a stepdown maneuver. These hip motions were significantly reduced during a stepdown maneuver following a 16-week strengthening program.[24] These results suggest that strengthening may improve movement patterns in individuals who present with abnormal mechanics, as they have a greater propensity for change. However, these results need to be further validated with studies involving additional subjects and examining more dynamic activities such as running.

Therefore, the purpose of this study was to examine the effect of a hip strengthening program on hip and knee mechanics during running and squatting in females who exhibit abnormal mechanics during running. **It was hypothesized that peak hip adduction, hip internal rotation, contralateral pelvic drop, and knee external rotation during running and during a single leg squat would be reduced as a result of the hip strengthening program**. Due to the lack of strength training stimuli, we expected no changes in hip or knee kinematics in the control group.

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METHODS

An *a priori* power analysis was conducted using an effect size of 1.00 (α=0.05, β=0.20) to determine the sample size of the study. An effect size of 1.00 was chosen as it conservatively represents a large effect.[9] Pilot data from 20 uninjured females (group mean peak HADD during running=18.4°, sd=4.3) were utilized for the power analysis. Peak HADD during running was chosen for the power analysis as this variable has previously been shown to be associated with females with PFPS in our previous studies and with other lower extremity injuries in runners.[11,29,32,41] We found that a minimum of 9 subjects per group were required to adequately power this investigation. To account for a 10% drop out rate, we chose to recruit 10 subjects per group.

Prior to participation, all subjects signed an informed consent that was approved by the University of Delaware Human Subjects Research Board. To be included, subjects had to be female, between the ages of 18-35 years and running at least 6 miles/week. In addition, all subjects were required to abstain from any lower extremity resistance training for at least 90 days prior to enrollment in the study. Each subject was required to attest that they were free of any musculoskeletal condition or surgery that would affect their running or squatting mechanics.

<u>Baseline Screening</u>

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All potential subjects underwent a baseline screening to determine if they met the inclusion criteria of abnormal hip mechanics during running. Thirty-five retroreflective markers were attached to bilateral lower extremities to analyze running kinematics (VICON, Oxford, UK). Anatomical marker placement was recorded via a marker placement device (MPD) as shown in Figure 1. This device has been shown to increase the day-to-day reliability of kinematic data.[30] Subjects wore standardized neutral running shoes (Nike Pegasus, Beaverton, Ore). Following a 5 minute warm-up, five consecutive strides were collected while subjects ran at 3.35 m/sec (8 min/mile pace) on an instrumented treadmill (AMTI, Watertown, MA). Stance was determined utilizing a threshold of 50 N. Hip joint centers were calculated via a spherical hip trial.[17] Finally, single leg squat data were collected. During the single leg squat, subjects were asked to maintain single leg stance with the upper extremities held horizontally to assist with balance. While in this position, subjects squatted to approximately 60 degrees knee flexion maintaining a rhythm of a 1 Hz beat for the both the descending and ascending phases. Data were collected while the subjects performed 5 consecutive squats. All kinematic and kinetic data were sampled at 200 Hz and 1000 Hz, respectively.

Data were then analyzed. All kinematic and kinetic data were filtered with an 8- and 50-Hz, low-pass, fourth-order, zero-lag Butterworth filter, respectively. 3-D joint and segment angles were calculated with Visual 3-D software (C-Motion Bethesda, MD). All joint angles were calculated in reference to the proximal segment. The pelvis segment was referenced to the lab coordinate system. Standing calibration angles were not subtracted from the motion trials. Customized software (LabVIEW 8.0, National

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Instruments, Austin, TX) was used to determine peaks and calculate means for the variables of interest. Kinematic variables of interest were peak hip adduction (HADD), peak hip internal rotation (HIR), contralateral pelvic drop (CPD), and peak knee external rotation (KER). For the single leg squat, kinematic variables were analyzed at 45° of knee flexion. This point was chosen as it corresponded with the approximate angle of peak knee flexion during running for this cohort.

Abnormal hip mechanics was operationally defined as HADD during running ≥20°. This value represented 1 standard deviation above the mean of a normative, mixed gender, database of healthy runners. Excessive peak HADD during running was chosen as the kinematic inclusion criteria because it has commonly been associated with several lower extremity running injuries.[11,29,32,41] All subjects with peak HADD during running ≥20° (obtained from their baseline data collection) were then invited to participate in the study. If both legs qualified, the leg with the greatest HADD was used. Subjects were blinded to the kinematic qualification criteria for the extent of their enrollment in the study. This was done to eliminate any potential conscious change in running gait by the subject. All qualified subjects were assigned to either a strength training (STR) or control (CON) group. Group assignment was block randomized to insure matching for age and weekly running mileage.

Hip Dynamometry Procedures

During the next visit, peak isometric hip abduction (HABDS) and external rotation (HERS) strength was measured via a handheld dynamometer (Nicholas, Lafayette, IN) according to methods of previous investigations.[11,42] HABDS was measured in sidelying

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while HERS was measured in prone with the hip extended. This position was used over a sitting position (hip flexed) so as to have the hip in a more similar position to that of running. The dynamometer was placed 5 cm proximal to the lateral knee joint line for all HABDS measurements. Similarly, the dynamometer was placed 5 cm proximal to the medial malleolus for all HERS measurements. The dynamometer was stabilized against the subjects with straps to eliminate the potential effect of examiner strength.[2] After a practice session, 3 trials per muscle group were collected. Subjects contracted with maximal effort for 3 seconds as peak torque production was recorded. Strength values were normalized to body weight and lever arm length (%Bw*m). For HABS, the lever arm was defined as the midpoint of the greater trochanter to the point of application of the dynamometer. For HERS, the lever arm was defined as the midpoint of the lateral femoral condyle to the point of application of the dynamometer on the tibia. The peak of three maximal effort trials was used for analysis**. Intrarater reliability (ICC equation 3,K) for HABDS and HERS measures were 0.96 and 0.91, respectively.**

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Strengthening Program

Subjects in the (STR) group completed a 6-week, 3x/week hip strengthening protocol targeting the hip abductors and external rotators. Six weeks was chosen to be consistent with clinical studies addressing PFPS.[3,10,16,28] Additionally, it has been shown that 80% of the strength changes noted within this time interval have been attributed to muscular factors. In programs that are four weeks in length or less, strength gains have been shown to be primarily due to changes in neuromuscular control.[25] Sessions were conducted on non-consecutive days to allow for adequate recovery. Exercises were progressed weekly under the supervision of a licensed physical therapist who is board certified in orthopedics (co-author RW). Each week, the first exercise session was conducted with the physical therapist. The remaining two sessions were completed independently. Exercise compliance was monitored via an exercise log that each subject maintained. Exercises were conducted in two sets of ten repetitions. Isometric hold times, resistance levels, and degree of external support were designed to cause significant fatigue by the end of the second set. This level of stimulus has been suggested to cause an increase in muscle strength when applied 3x/week for at least six weeks.[14]

Each week, subjects were issued two exercises (Table 1). Subjects completed the strengthening exercises with both lower extremities. For the first two weeks, exercises were performed in a non-weight bearing position (Figure 2). Emphasis was placed on contracting the HABD and HER musculature, which was confirmed by palpation by the physical therapist. For the final 4 weeks, exercises were progressed to weight bearing positions (Figure 2 and 3). For all exercises utilizing resistance bands (Perform Better, Cranston RI USA), a level of resistance was chosen for each subject that resulted in failure by the end of the second set. During all weight bearing exercises, proper lower extremity alignment was emphasized. These instructions included keeping the center of the patella in line with both the anterior superior iliac spine proximally, and with the second toe distally. Subjects were also instructed to keep their patella pointing “straight ahead” to control HIR. Subjects received visual feedback from a mirror and verbal feedback on alignment from a physical therapist. During the final three weeks, single leg

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squat exercises were added (Figure 3). The difficulty of the squats was increased in week five by decreasing external support (Figure 3b). For the final week, a resistance band was added requiring the subjects to resist an external adduction force (Figure 3c). Subjects in **the CON group did not receive any form of intervention for the six week period**. All subjects, regardless of group assignment, were required to maintain their weekly running mileage (+/- 10%) for the duration of their involvement in the study. Weekly mileage was recorded via a mileage log.

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Follow-Up Data Collection

Following either the six-week intervention or the control period, all subjects returned for a follow-up strength and motion analysis session. This time, data were only collected on the qualified limb. The MPD was used to assist with placement of the anatomical markers using the positions recorded during the first visit. A previously traced standing template was used to standardize foot position in the lab coordinate system for both the standing calibration and the single leg squat trials. The collection and analysis of running and squatting were repeated as described previously. Hip strength measures were also repeated as described previously. Subjects were debriefed on all blinded inclusion criteria at the conclusion of their involvement in this study.

Statistical Analysis

This study utilized a two-way analysis of variance (ANOVA) with a repeated measures design (group(2) x time(2)). Strength measures and peak joint angles were the primary variables of interest and were analyzed statistically. When an interaction was detected ($p \leq 0.05$), simple main effects were examined. The Kolmogorov-Smirnov test ($p \leq 0.05$)

was conducted on the difference scores to ensure normality for all variables with significant main effects. For normally distributed variables with significant main effects, post hoc dependent t-tests were conducted and effect sizes (Cohen's *d*) were calculated. For any variables that were non-normally distributed, Wilcoxen-Signed Rank test and the Glass's delta (effect size) was utilized for post hoc contrasts. An alpha level of $p \leq 0.05$ was chosen for all comparisons. Group means and standard error of the mean (SEM) were also calculated for all variables with normal distributions. Median and standard deviation scores were calculated for the variables that were not normally distributed. Data were analyzed using SPSS (Version 18, IBM, Somers, NY).

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RESULTS

A total of **forty-three female runners (HADD during running=18.3°± 3.2)** were screened to obtain the 20 subjects that met the excessive HADD criteria of 20°. Independent t-tests failed to reveal any differences between the STR and CON groups for age, weekly running mileage, and BMI at baseline Table 2. STR subjects completed the intervention with a 100% compliance rate. Subjects in both groups reported full compliance with running mileage and activity restrictions.

A significant interaction was noted for both strength measures (*F=34.58, p=0.000)*. Assessment of the simple main effects indicated that the STR group improved in their HABDS and HERS by 41.6% (±21%) and 40.0% (±12.5%) respectively, while the CON group strength remained unchanged (Table 2). Post hoc analyses of simple main effects revealed that these increases were highly significant (and associated with large effect sizes) for the strength trainers. The control subjects failed to show any changes in HABDS and HERS strength. Thus, in the absence of a strengthening stimulus, these strength measures for the control group were consistent over time.

All running data were normally distributed with the exception of HADD for the CON group (Kolmogorov-Smirnov test: D(10)=0.266, p<0.05). Analysis of the running data failed to reveal an interaction for any of the peak kinematic variables of interest. In addition, no main effects across conditions for either HADD, HIR, or CPD were detected. Due to the lack of interaction, simple main effects were not examined. (Table 4, Figure 4). There was a significant main effect for KER across conditions (F=7.070 p=0.026) indicating a difference between groups. However, no significant main effect for KER across time was detected (F=0.113 p=0.744), suggesting no overall intervention effect.

All SLS data were normally distributed with the exception of CPD for the STR group (Kolmogorov-Smirnov test: *D(10)=0.289, p<0.05)*. HADD demonstrated a significant interaction (*F=5.565 p=0.043)* as did HIR (*F=5.931 p=0.038),* and CPD (*F=5.082 p=0.05)* (Table 4, Figure 5). Post hoc analysis of simple main effects revealed significant reductions for all three of these variables for the strengthening group. Both HADD and HIR reductions during the single leg squat were associated with large effect sizes. However, no significant changes were detected for the control group. There was a trend of a significant interaction for KER (*F=4.859 p=0.055).* Thus, we chose to

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analyze simple main effects for KER. A trend towards a reduction in KER was detected for the training group (*p=0.06*) but not for the controls (*p=0.14*).

DISCUSSION

This study sought to determine the effect of a hip strengthening program on running and single leg squat mechanics in female runners who exhibit abnormal hip motion. Large gains in HABDS and HERS were noted in the STR group. While the strengthening program was effective at altering hip mechanics during a single leg squat, no changes in running mechanics were noted. Thus, the results of this study only partially confirmed our hypotheses.

For the STR group, the intervention was successful at increasing hip strength. The exercises chosen, which utilized body weight and elasticized bands for resistance, have been shown to invoke high activity from the hip abductors and external rotators.[12,36] Having abstained from any lower extremity strength training for at least 90 days prior to entry into the study, the large gains in strength were not surprising. The strength increases seen in this study (HABDS: 41.6%, HERS: 40.0% increase) were greater than that noted by Snyder et al., (2008) (HABDS: 13%, HERS: 19.6% increase).[37] However, these authors focused on healthy individuals with normal hip mechanics. In addition, their subjects were not required to refrain from strength training prior to the study. As a result, they may have been stronger at baseline, and their capacity for strength gains may have been reduced. In contrast, Mascal et al (2003) reported greater than a two-fold increase in strength (HABDS: 50%, HERS: 317%) compared with our findings.[24] However, these authors focused on a patient with pathology and associated excessive

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hip adduction and hip internal rotation during functional movements. Additionally, the strengthening program utilized by Mascal et al. was 14 weeks long. These factors may have led to the greater strengthening seen in that study.

Despite the increases in hip strength, there were no significant reductions in peak HADD, HIR, and CPD during running. This finding is in disagreement with our hypothesis. With the exception of KER, the two groups were not statistically different at baseline or post training. The group main effect of increased KER observed in the STR subjects is likely related to the greater (though nonsignificant) HIR seen in this group both at baseline and post training. The subjects in this present study had a large capacity for changes in mechanics due to their abnormal hip mechanics. However, despite the relatively large changes in strength, running mechanics were not significantly altered. This suggests that strengthening alone may not be adequate to alter the underlying abnormal movement patterns that may be associated with pathology.

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A component of neuromuscular retraining during running may be needed to actually alter abnormal running mechanics. In fact, a recent study by Noehren et al (2010) reported significant improvements in hip mechanics following a neuromuscular-only intervention.[31] In Noehren et al., 2010, female runners with PFPS and excessive hip adduction underwent an 8-session gait retraining program. Subjects were provided realtime kinematic feedback on HADD while they ran on an instrumented treadmill. Subjects were then encouraged to match their HADD curve with a target curve. These subjects had similar running mechanics as the runners in the current study. However, the changes in running mechanics reported by Noehren et al. (2010) were large (reduction of HADD by 5.0º, CPD by 3.0º, and HIR by 3.0º). More importantly, their subjects experienced complete resolution of their pain. Perhaps most significantly, these changes persisted at 1 month post-intervention.[31] In contrast, the current study failed to demonstrate any changes in running mechanics following strengthening. Thus, neuromuscular interventions that are activity-specific may result in greater improvement of aberrant mechanics than a strengthening-only intervention.

While no changes were noted in running mechanics, significant reductions were noted during the single leg squat. As hypothesized, peak HADD, HIR, and CPD during the single leg squat were reduced. In fact, the contralateral pelvis actually became more elevated (-0.8º to -4.6º) following the intervention, hence the negative value. The reductions in peak motions of the hip during the single leg squat were of similar magnitude to those seen in Mascal et al. (2003) during a stepdown maneuver.[24] While their intervention did involve strengthening, a large component of the program involved neuromuscular training specific to the single leg stance maneuvers. As a result, the authors acknowledged the potential influence of neuromuscular training on their results.[24] **This may explain the improvement in mechanics seen in the single leg squat of the current study as it, too, had a large component of single leg stance activities. Neuromuscular training specific to the single leg squat consisted of mirror and verbal feedback on technique. Thus, these changes in single leg squat mechanics may reflect the acquisition of a new movement skill, rather than due to**

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the changes in isometric muscular strength noted. Indeed, the changes in hip mechanics during the SLS were on the same magnitude as those reported by Noehren et al., 2010.[31] In terms of the knee, KER was reduced, but as with running, not significantly (*p=0.06*). However, the reduction was twice that of running and the effect size was larger (0.61 vs. 0.45), again potentially related to the specificity of training for single leg squatting.

In future studies, other variables of strength, such as muscular endurance, should be examined. It has been shown that muscular endurance of hip musculature is a significant predictor of hip mechanics during running in females with PFPS.[39] In addition, muscular fatigue as a result of prolonged running may also play a significant role in abnormal hip mechanics in females with PFPS.[11] Secondly, isometric strength testing was utilized in order to translate the findings more readily to the clinical setting. Isokinetic testing may have higher validity for dynamic movements such as running.[5] Further study of improving muscular endurance, perhaps evaluated with isokinetic testing, on abnormal hip mechanics during running is needed. **In addition, results of this study suggest that future investigations should include a comparison of neuromuscular only versus strengthening only interventions.** This should help to further clarify the underlying mechanism of changes in single leg squat mechanics.

Proximal hip strengthening programs, such as the one described in this study, are often prescribed for patients with PFPS. However, high rates of recurrence of symptoms have been reported in conventional programs for the treatment of PFPS.[1,21] This may be due to a lack of alterations in faulty movement patterns. If the underlying mechanics of PFPS are not addressed, then the risk for recurrence is likely to be increased. Individuals with recurring PFPS may be at greater risk for developing patellofemoral osteoarthritis later in life.[43] Neuromuscular interventions, such as gait retraining, may have the greatest potential to directly mitigate any faulty mechanics associated with the injury. However, deficits in hip strength *and* abnormal hip mechanics have previously been noted in females with PFPS. Therefore, clinicians should consider both strengthening and neuromuscular interventions to address both impairments to reduce the risk of recurrence or the development of PFPS.

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Conclusion

The data presented in this study suggest that strengthening alone may be insufficient to alter abnormal movement patterns of the lower extremities during running. Despite large and significant gains in the strength of the hip abductors and hip external rotators, no changes were seen in abnormal hip mechanics during running. In contrast, reductions in hip abduction, hip external rotation, and contralateral pelvic drop were seen during single leg squatting. While these kinematic changes may have been due to the gains in hip strength, they may have resulted from the neuromuscular training that was specific to single leg squatting. **These results suggest that strengthening alone may not be sufficient to elicit changes in abnormal hip mechanics during running.**

Key Points

<u>Findings</u>

Hip strengthening alone may not be sufficient to change abnormal hip mechanics during running. Activity-specific neuromuscular training may be necessary to alter these aberrant motions.

Implication

Clinicians should incorporate neuromuscular training into therapeutic and intervention programs if normalization of abnormal running patterns is desired.

Caution

These results are only directly applicable to individuals who are pain-free females with abnormal hip mechanics.

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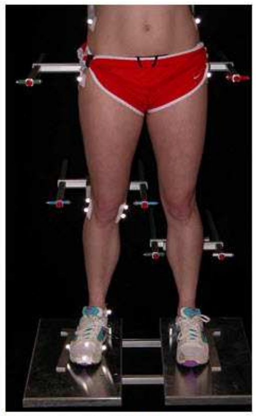

FIGURE 1: Anatomical marker placement was recorded during the baseline visit using the Marker Placement Device (MPD).[30] At the final data collection, anatomical markers were mounted according to the baseline coordinates.

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a. b.

FIGURE 2. a) Example of non-weight bearing exercise. During this straight leg raise exercise, a primary focus was on proper activation of the hip abductor (HABD) musculature by applying slight extension force against the wall. **b)** Example of weight-bearing exercise. Isometric HABD and HER at wall: While in contralateral pelvic elevation, subjects performed isometric HABD against the wall with the non-weight bearing leg. Simultaneously, the stance leg was held in HER.

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a. b. c.

FIGURE 3: Single leg squat progression. Subjects were instructed to perform a neutral lower extremity alignment during all single leg squat exercises. a) Single leg squat with one hand support, b) Single leg squat without support, c) Single leg squat with theraband-applied resistance in the direction of adduction.

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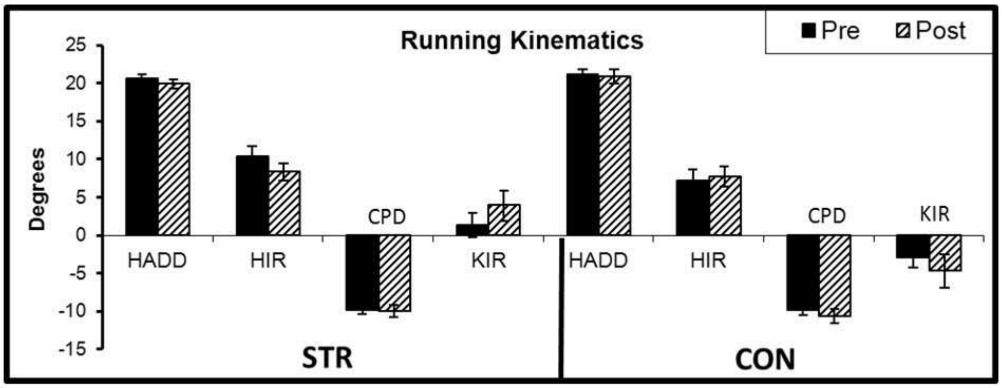

FIGURE 4: Comparison of running kinematics pre and post training. CPD is negative whereas contralateral pelvic elevation is positive. KIR is positive whereas knee external rotation is negative. Note the lack of differences in both the STR and CON groups at the end of the six-week intervention.

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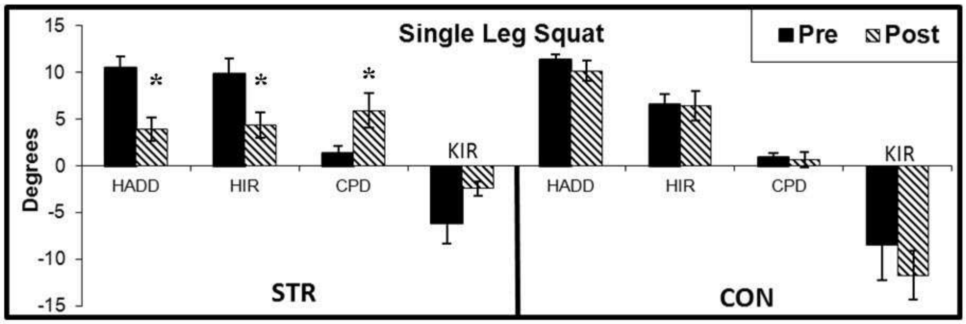

FIGURE 5: Comparison of single leg squat kinematics pre and post training. CPD is negative whereas contralateral pelvic elevation is positive. KIR is positive whereas knee external rotation is negative. Note that the STR group demonstrated a significant decrease in HADD and HIR while increasing CPD. * indicates $p \leq 0.05$.

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TABLE 1: Training program utilized for the intervention focusing on hip abduction (HABD) and hip external rotation (HER).

Week of Study	Exercise 1: (no. of sets x no. of reps, length of hold)	Exercise 2: (no. of sets x no. of reps, length of hold)
Week 1	Sidelying HER/ Hip Extension Exercise: 2x10, 5 seconds hold	HABD Straight Leg Raise: 2x10, 5 seconds hold
Week 2	Resistance Band Clam Shell (HER): 2 sets of 10 reps, no hold	HABD Straight Leg Raise: 2x10, 10 seconds hold
Week3	Bilateral Squat with Resistance Band targeting HER: 2 sets of 10 reps, 5 second hold	Contralateral Pelvic Hike (HABD) with Ball: 2x10 reps, 5 seconds hold
Week 4	Theraband-resisted side stepping (HABD):2 sets of 10 reps, no hold	SLS with Stabilization with Hand: 2x10 reps, no hold
Week 5	Isometric HABD and HER at wall: 2x10, 5 seconds	SLS w/o Stabilization: 2x10 reps, no hold
Week 6	Isometric HABD and HER at wall: 2x10, 10 seconds	SLS w/o Stabilization, with Resistance Band Targeting HABD: 2x10 reps, no hold

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TABLE 2: Subject Demographics: Mean (SEM).

	STR	CON
AGE (years)	22.7 (1.11)	21.2 (0.70)
BMI (kg/m²)	22.3 (0.73)	22.19 (0.92)
Weekly Running Mileage (mi/wk)	13.5 (1.67)	14.0 (2.32)

STR=Strength trainers, CON=Controls

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TABLE 3: Hip strength measures at baseline and post: Mean (sd). ** indicates $p \leq 0.05$

	Pre	Post	*p*	*d*
STR				
HABDS (%BW*m)	7.2 (1.2)	10.0 (1.1)	***0.0006****	1.39
HERS (%BW*m)	2.9 (0.4)	3.6 (0.4)	***0.0003****	0.62
CON				
HABDS (%BW*m)	9.2 (0.03)	9.3 (0.01)	*0.85*	0.06
HERS (%BW*m)	3.4(0.009)	3.4 (0.003)	*0.33*	0.06

HABDS= Hip abduction strength. HERS= Hip external rotation strength. STR=Strength trainers, CON=Controls.

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